

**GAS FLOW CONTROL FOR GAS BURNERS UTILIZING A MICRO-
ELECTRO-MECHANICAL VALVE**

FIELD OF THE INVENTION

[001] The present invention is generally related to cooking appliances, and, more particularly, to a micro-electro-mechanical (MEMS) valve for providing a variable gas flow control for gas burners.

BACKGROUND OF THE INVENTION

[002] Gas cooking ranges typically include a manually operated gas valve positioned in a gas line between a gas source and a burner to control gas flow to the burner. Turning of an indicator knob connected to the gas valve selectively opens or closes an orifice in the valve to allow gas to flow through the burner. Unlike electric heating elements that may be electronically controlled and programmed, a user must directly control gas flow in typical gas cooking range, and changes to the flow can only be made by physically moving the knob to adjust the gas flow. To achieve remote control and programmability of gas burners, advanced gas burner ranges may incorporate proportional solenoid valves, motor driven valves, or binary poppet valves, for example, controlled via an electronic touch pad. However, such electro-mechanical controls are not suited for appliances because they are complex, require a relatively large footprint for incorporation in a gas range, may be less reliable than manual valves, may not be suitable for use in a high heat environment, and may be prohibitively expensive to manufacture and maintain. In addition, proportional control at low gas flows using electro-mechanical controls has been difficult to achieve. Micro-electro-mechanical system (MEMS) valves have been proposed for low flow, high-pressure applications. Typical MEMS valves may include a silicon or polymer based microvalve, and may be operated by electrostatic, electromagnetic, shape memory alloy (SMA) or piezoelectric actuation. However, such valves are not believed to be suited for low pressure, high flow applications.

BRIEF DESCRIPTION OF THE INVENTION

[003] An electronically controlled gas burner system is presented that includes at least one gas burner and a micro-electro-mechanical valve comprising a plurality of microvalves in fluid communication with the gas burner. The system also includes a microvalve controller for controlling the opening of each of the microvalves in the micro-electro-mechanical valve.

[004] A method for controlling a plurality of microvalves for firing a gas burner is presented that includes issuing a command for a desired gas flow and controlling an opening of at least some of the microvalves valves to provide the desired gas flow corresponding to the command.

BRIEF DESCRIPTION OF THE DRAWINGS

[005] FIG. 1 is an exemplary diagram of a gas burner system comprising a MEMS valve coupled to a burner.

[006] FIG. 2 is an exemplary diagram of a gas burner system comprising a MEMS valve having portions of a plurality of microvalves coupled to respective burners.

[007] FIG. 3 is an exemplary diagram of a gas burner comprising an array of microvalves.

DETAILED DESCRIPTION OF THE INVENTION

[008] FIG. 1 is an exemplary diagram of a gas burner system 10 comprising a micro-electro-mechanical system (MEMS) valve 12 coupled to a burner 14. The MEMS valve 12 may include one or more microvalves 16, for example, configured in an array. Each of the microvalves 16 may be coupled, for example, by an electrical conductor, to a valve controller 18 for controlling the opening and closing of each of the microvalves 16 in the MEMS valve 12. An output 17 of each of the microvalves 16 may be in fluid communication with the burner 14, and an input 15 to the each of the microvalves 16 may be in

fluid communication with a gas supply 20. Accordingly, each of the microvalves 16 in the MEMS valve 12 may be independently controlled to open or close the microvalves 16, allowing gas to flow from the gas supply 20 to the burner 14 at a desired rate.

[009] In the past, it was believed that the low flow characteristics of conventional MEMS valves precluded their use in gas burner applications. However, the inventors of the present invention have innovatively realized that by using an array of microvalves, improved electronic control of gas burners may be provided. Moreover, because the microvalves may be individually operated, proportional control, offering fine control at low burner powers, may be provided. Furthermore, a MEMS valve incorporating a number of microvalves in an array configuration offers the advantages of low cost, reliability, simplicity, small footprints, and heat resistance. Examples of microvalve devices that were used in a prototype constructed for experimental purposes include those as described in U.S. Patent Nos. 6,149,123 and 6,523,560. It will be appreciated that the present invention is not limited to the foregoing devices since the array aspects of the present invention may be practiced with any type of microvalve devices.

[010] In an aspect of the invention, the microvalves 16 in the MEMS valve 12 may be operated in a continuously variable, or analog, fashion to provide a variable range of microvalve 16 openings, and consequently, variable gas flow from the valve, depending on a degree of opening of the microvalve 16. In another aspect of the invention, the microvalves 16 in the MEMS valve 12 may be operated in a binary fashion. For example, the microvalve controller 18 may provide a two state control signal having a first state for controlling a microvalve 16 to a closed position, and a second state for controlling the microvalve 16 to an open position. Accordingly, different numbers of microvalves 16 in the MEMS valve 12 may be opened or closed to provide variable gas flow. For example, in an array comprising ten microvalves 16, one of the microvalves 16 may be opened to provide a lowest setting for gas flow to the burner 14. Progressively larger numbers of microvalves 16 may be

opened to provide increasingly higher gas flows. Accordingly, all 10 of the microvalves 16 in the MEMS valve 12, may be opened to provide a highest setting for gas flow. In an aspect of the invention, the number of microvalves 16 selected for the MEMS valve 12 may be based on the total gas flow required to fire the burners 14 at a desired burner rating, and the gas flow capability of each valve 12. For example, if a burner requires a total gas flow of 0.18 standard cubic feet per minute (SCFM) to operate at a desired BTU capability, and each valve in the array can provide 0.018 SCFM, then ten valves ($10 \times 0.018 = 0.18$ SCFM) may be used to control the gas flow to the burner.

[011] In yet another aspect, the microvalve controller 18 may include another module, such as a pulse width modulator (PWM) 24, to sequentially turn each of the microvalves 16 on and off periodically at a desired duty cycle when the respective microvalve 16 is turned on by the microvalve controller 18. For example, a duty cycle of from 90% to 10% may be used, while a duty cycle of 60% to 40% is believed to promote most stable burning. By modulating the opening and closing of each of the microvalves 16 in this manner, it is believed that combustion in the burner 14 may be made more efficient.

[012] In another aspect of the invention, the microvalve controller 18 may be programmed via an electronic interface 22. For example, the electronic interface 22 may include a user interface, such as a touch pad, to allow a user to control a burner 14 gas flow setting for cooking. The electronic interface 22 may also provide a programmed gas flow pattern that varies with respect to time, such as an initial comparatively higher flow rate for first desired time period and a comparatively lower flow rate for a second desired time period. In addition, the electronic interface 22 may allow remote control of the gas burners 14 via a communications interface such as Bluetooth®, registered by Bluetooth SIG, Inc, compatible interface.

[013] The system 20 may also include at least one sensor 26 to monitor a burning condition at the burner 14. For example, the sensor 26 may be

positioned near the burner 14 for monitoring conditions such as temperature or carbon monoxide formation. The sensor 26 may provide such information to the microvalve controller 18 in a feedback loop 28. The microvalve controller 18 may then control the opening of at least some of the microvalves 16 to adjust the gas flow to the burner 14 according to the information received from the sensor 26.

[014] FIG. 2 is an exemplary diagram of a gas burner system 30 comprising a MEMS valve 12 having portions 32, 34, 36, 38 of an array of microvalves 16 coupled to respective burners 14. For example, each burner 12 may be fluidically connected to a respective portion 32, 34, 36, 38, and each portion may be controlled by the microvalve controller 18. In FIG. 2, gas input connections for a gas source, such as the gas source 20 shown in FIG.1, have been omitted for clarity. As depicted in FIG. 2, the MEMS valve 12 may be centrally located with respect to a plurality of burners 14 so that different portions 32, 34, 36, 38 of the MEMS valve 12 may be used to fire each of the burners 14. For example, the microvalve controller 18 may be configured to provide independent control of each portion 32, 34, 36, 38 of the MEMS valve 12. In addition, each valve 12 in each portion 32, 34, 36, 38 may be controlled independently to provide variable gas flow to the burner 12. Each portion 32, 34, 36, 38 may include an appropriate number of microvalves 16 to provide a gas flow required to fire the respective burner 12 coupled to the portion 32, 34, 36, 38. The gas burner system 30 may further include the elements described above, such as a PMW module 24, an electronic interface 22 and a sensor 26 as shown in FIG. 1.

[015] FIG. 3 is an exemplary diagram of a gas burner 40 comprising an array of MEMS microvalves 16. In FIG. 3, gas connections to the inputs 15 of each of the microvalves 16 to a gas source, such as the gas source 20 shown in FIG.1, have been omitted for clarity. In an aspect of the invention, the microvalves 16 may be positioned integrally or otherwise within the burner 40 to contribute to a flame produced by the burner 40. For example, the microvalves 16 may be positioned circumferentially in a circular burner so that

the output 17 of each the microvalves 16 is oriented to contribute to flames around a periphery of the burner 12. Each of the microvalves 16 may be independently controlled by the microvalve controller 18 to open or close the microvalves 16 to allow gas to flow from the microvalves 16 at a desired rate. The gas burner system 30 may further include the elements described above with respect to FIG. 1, such as a PMW module 24, an electronic interface 22 and a sensor 26 as shown in FIG. 1

[016] It is believed that a MEMS valve comprising an array of microvalves as described above could be constructed as follows. For example, the MEMS valve may be configured to have a 15 x 15 millimeter (mm) footprint and include 100 microvalves. The microvalves may be grouped in groups of 10. Each group of 10 valves may be configured to have a collective binary action, so that either all valves in the group are fully open, or completely closed. Accordingly, ten different cumulative flow levels may be provided. Each group may be configured to provide a flow level of 0.0180 SCFM, so that a flow level of 0.0180 SCFM is provided when one group is "on" (for example, for a low cooking setting) and 10 times 0.0180 SCFM or 0.180 SCFM when all ten groups are "on" (for example, for a high cooking setting.) The exemplary MEMS valve may include microvalves having piezoelectric polymer actuation, and be a normally closed type microvalve.

[017] It is believed that a MEMS valve configured as described above could provide electronically controlled proportional flow and operate at 2 to 10 inches of water (iwc). The flow variation may be less than +/- 10% at a minimum flow and +/- 5% at a maximum flow. The microvalves may have a 0.25 second response time. It is believed each of the valves could operate for 100,000 cycles with 95% confidence level. Furthermore, it is believed the array controller would use less than 10 watts of electrical power to control the microvalves in the array.

[018] While the preferred embodiments of the present invention have been shown and described herein, it will be obvious that such embodiments are

provided by way of example only. Numerous variations, changes and substitutions will occur to those of skill in the art without departing from the invention herein. While an exemplary embodiment of a cooking appliance for use in stove is described, the invention may be used any application having a gas burner. Accordingly, it is intended that the invention be limited only by the spirit and scope of the appended claims.